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Concept for Employing Automatic Continuous-Weighing Equipment in Mechanized Citrus-Packing Operations

Method and Cost Factors

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CONTENTS

Page
Acknowledgments iv
Abstract 1
Introduction 1
Procedure 2
Results, calculations, and interpretations 2
  Overcount and undercount bags 2
  Controlling average bag weight 6
Proposed equipment 10
Revenue and cost factors 10
Conclusions 11
References 13

ILLUSTRATIONS

Fig.
1. Average weight of bags of correct number of fruit in sample lots and three-standard-deviation range of weights of those bags for each sample lot 3
2. Distribution of weights in a sample lot of 100 bags and their standard-deviation and three-standard-deviation ranges 4
3. Basic layout for automatic continuous-weighing scale and accessories 8

TABLES

1. Numbers and percentages of bag samples within count or weight categories and average bag weights 3
2. Normal curve areas 5
3. Possible additional number and value of 5-lb polyethylene bags of fruit as result of correcting overcount bags 7
4. Weight and value of fruit that can be saved by adjusting for reduced average bag weight 7
5. Initial investment and annual ownership costs for equipment 9
6. Annual ownership and operating costs for equipment 9
7. Estimated labor costs for handling 5-lb bags rejected for specific conditions when using automatic continuous-weighing equipment 10
8. Numbers and costs of 5-lb polyethylene bags involved in correcting for overcount filling 10
9. Costs of 5-lb polyethylene bags involved as underweight in adjusting for reduced average bag weight 11
10. Combined revenue and cost effects as result of using automatic continuous-weighing equipment 12

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Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE
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Concept for Employing Automatic Continuous-Weighing Equipment in Mechanized Citrus-Packing Operations

Method and Cost Factors

By Earl K. Bowman[1]

ABSTRACT

Among the potential benefits of using the proposed equipment, which consists of a spacing conveyor, continuous-weighing scale, reject mechanism, and electronic tallying device, are rejection of overcount bags for correction to save fruit; reduction of average bag weight to save fruit, with the assurance that underweight bags will not be shipped; and elimination of unnecessary discarding of undercount bags that meet minimum weight requirements. Projected revenue and cost effects for correction of bags containing more than a specified number of fruit and for reduction in average bag weight were based upon actual number of fruit per bag and bag weights from data obtained in research on machine-bagging operations in Florida citrus packinghouses. Net increase in packinghouse revenue as a result of adopting the concept presented in this report could be as much as $24,000 on an annual volume of 2.5 million 5-pound bags and $40,000 on an annual volume of 4.5 million bags. About $9,000, based on 1977 prices, would be required to purchase the equipment, which has a rated capacity of 120 packages per minute.
KEYWORDS: automation, bagging machines, citrus packing, conveyors, counting machines, mechanization, reject mechanisms, scales.

INTRODUCTION

The level of mechanization involved in packing citrus fruit in consumer bags in Florida packinghouses has progressively increased (Bowman and Teele 1973), and the investment cost for the automatic bagging machines involved is normally high (Bowman 1977). During the 1976–77 season, 14.1 percent of the approximately 58.5 million 4/5-bushel boxes of fresh citrus marketed from Florida was packed in consumer bags, with the 5-pound size accounting for 93.6 percent of the total shipped in bags (Florida Department of Agriculture and Consumer Services 1976–77).

The automatic machines now generally in use count the number of fruit passing through a sensing field and provide control response to shut off the flow of fruit and trigger the closing action for each bag cycle when a preset number of fruit to fill the bag to desired weight has been registered (Bowman 1977; Grierson 1969; Grizzell

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[1] Industrial engineer, Handling and Facilities Research Unit, Agricultural Research Service, U.S. Department of Agriculture, Gainesville, Fla. 32604.

1963). Studies show, however, that there is usually sufficient variation in the quantity-metering response of the equipment to produce some bags that are undercount and some that are overcount. Also involved in the variation in weights of machine-filled bags of fruit is the characteristic variability in fruit weights within a given fruit size and the combinations of fruit weights delivered, from bag to bag, in machine packing.

Count-action machines were of two basic types. One employed a photocell beam for sensing the count as fruit was moved in single file on a small, high-speed conveyor belt. The other, usually having three channels, moved fruit at lower speed beneath levers that, from movement by contact with each fruit, operated microswitches to sense the count. Automatic start-stop of the conveyor was the action used for quantity metering in both types of machine.

Satisfactory quantity metering must always be of concern to packinghouse managers. In Florida, it must be in terms of filled-bag weight (Bowman 1977). If underweight bags are allowed to reach markets, severe problems involving both legality and customer response can arise. On the other hand, bags exceeding the weight required to maintain a minimum weight can cause loss of revenue to the industry.

With a continuous-weighing scale and automatic reject attachments, management could select underweight and overweight set points, enabling control of the bagging operation far beyond just the rejecting of overcount and undercount bags. Average bag weight might be controlled to save a significant amount of fruit weight in packing a given number of bags and also assure that bags weighing less than a desired minimum would not be shipped out.

The work covered in this publication was done as part of a continuing program focused on improved systems for preparing citrus and subtropical fruits and vegetables for market. The purpose of the report is to present a concept for employing automatic continuous-weighing equipment in mechanized citrus-packing operations, drawing upon research data on available machine-packing operations. Method and cost factors are explained and analyzed, and the effects that would be expected from such an operation are presented. No scale facilities were available for experimentation and trials with the proposed method. Initial investment prices for equipment and annual operating and supply expenses are based on costs in 1977.

PROCEDURE

Data were obtained on weights of filled bags and weights of individual fruit taken from the bags that were weighed as part of a research effort that focused on design and operating behavior of automatic packing equipment and its output capability. Bags were randomly picked from the takeaway conveyors of automatic packing machines and replaced after they were weighed and the fruit in each counted. Generally, 100 bags were weighed as 1 sample. Five to ten percent of the bags weighed were retained, and all fruit were removed from these bags to be individually measured and weighed. A precision scale, reading to 1 gram, was used for weighing individual fruit.

In analysis and interpretation of the data, statistical procedures based on the normal distribution (bell-shaped curve) were used. The following statistics were calculated: standard deviation of individual fruit weights, standard deviation of bag weights and weight ranges within which given portions of bagged fruit output would be expected to fall for a given average bag weight, and standard deviation of bag weights. Representative distributions of bag weights from samples were plotted.

RESULTS, CALCULATIONS, AND INTERPRETATIONS

OVERCOUNT AND UNDERCOUNT BAGS

The count-action machines underfilled and overfilled portions of their output of packed bags. Although this was also true for the manual check-weigh carrousel machine, underfilling, in terms of number of fruit, may be an acceptable, normal condition when, at the same time, bag weight is suitably controlled by manual check weighing, i.e., kept up to desired minimum weight, as was the case with the comparatively minimal percentage of bags (11 of 875 bags) that weighed under 5.25 pounds in samples from this machine (table 1).

In the prevailing method of packing fruit in

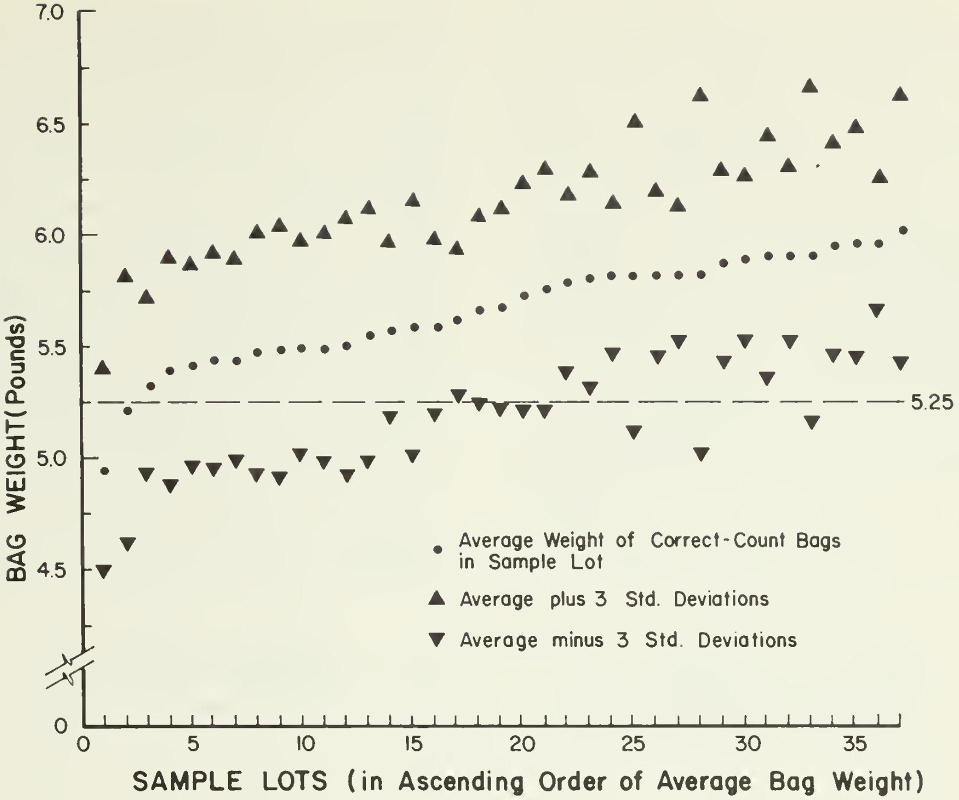

FIGURE 1.—Average weight of bags of correct number of fruit in sample lots and three-standard-deviation range of weights of those bags for each sample lot.

Table 1.—Numbers and percentages of bag samples within count or weight categories and average bag weights

Item		Type of bagging machine		
		Count-fill, photocell, single-channel	Count-fill, microswitch, multichannel	Manual check-weigh carrousel[1]
Sample lots	No.	16	7	9
5-lb bags	No.	1,494	589	875
Correct-count bags	No.	1,392	517	659
Do	pct	93.17	87.78	75.30
Undercount bags	No.	12	39	151
Do	pct	0.80	6.62	17.26
Overcount bags	No.	90	33	64
Do	pct	6.02	5.60	7.31
Bags under 5 lb	No.	4	18	1
Do	pct	0.27	3.06	0.11
Bags 5 to 5.25 lb	No.	55	92	10
Do	pct	3.68	15.62	1.14
Average bag weight:				
All bags	lb	5.70	5.55	5.82
Correct-count bags	lb	5.68	5.53	5.85

[1] Manual check weighing of bags includes adding and removing fruit and exchanging fruits hand-selected for size variation to adjust for desired bag weights.

small bags, which employs automatic count-fill machines and periodic manual checking of bag weight, it is necessary to maintain the average bag weight at about 0.50 pound above the generally accepted minimum shipping-point weight of 5.25 pounds. Otherwise, problems with shipping out underweight bags are likely to arise, i.e., low end of the range in bag weights dropping below 5.25 pounds because of the variation, usually about 0.50 pound above or below the average weight, that is characteristic of the distribution involved (fig. 1).

Applicability of normal-distribution formulas for fruit dimensions and packed bag weights has been recognized in the field of statistics. Mendenhall (1965) states that there are frequent occurrences of mound-shaped and bell-shaped distributions of data in nature and thus wide applicability of what he terms the "empirical rule". According to the rule, "Given a distribution of measurements that is approximately bell-shaped, the interval: (1) μ (mean) $\pm$ σ (standard deviation) will contain approximately 68 percent of the measurements. (2) $\mu \pm 2\sigma$ will contain approximately 95 percent of the measurements. (3) $\mu \pm 3\sigma$ will contain approximately 99.7 percent of the measurements."

Normal curve-area tables included in textbooks and handbooks on statistics give the percentage of measurements in the interval associated with any number of standard deviations (z) ranging from zero through 3.0. Such a table is included for convenient reference (table 2).

The distribution of a sample of 100 actual packed-bag weights is shown in figure 2. An approximately normal distribution pattern, or bell-

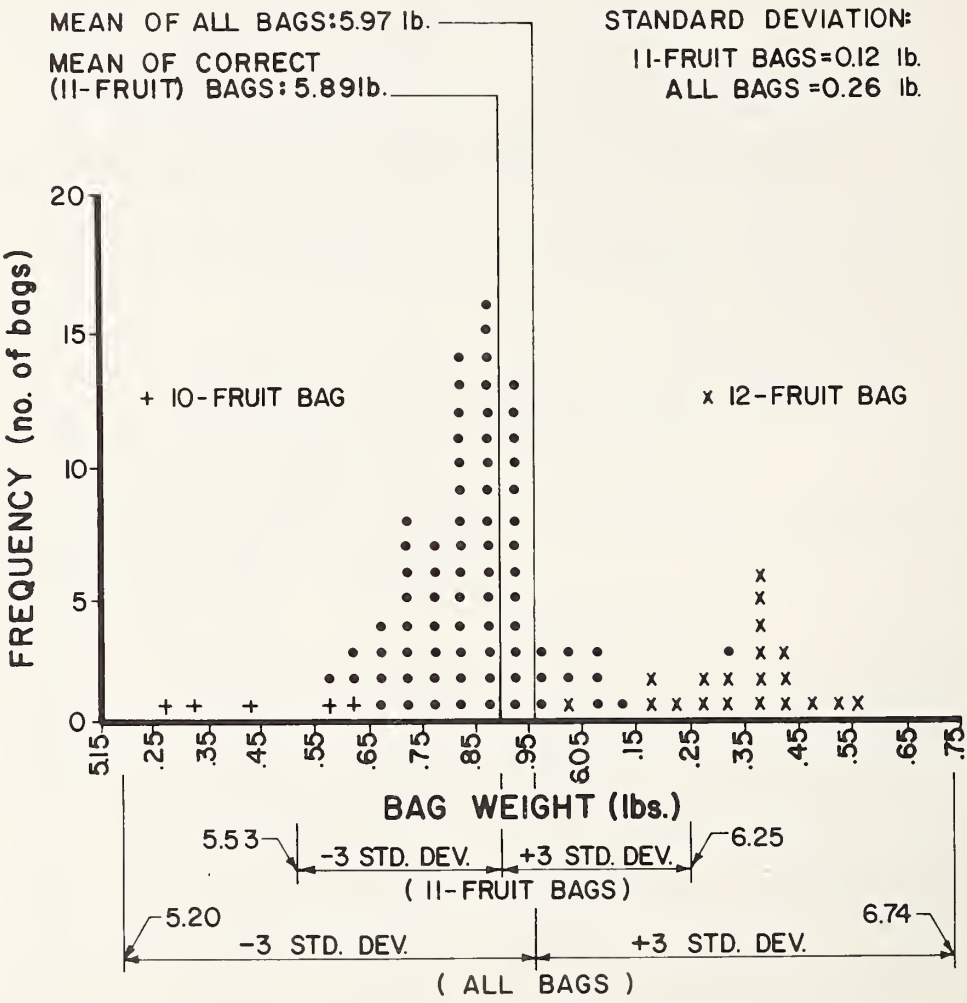

FIGURE 2.—Distribution of weights in a sample lot of 100 bags and their standard-deviation and three-standard-deviation ranges.

shaped curve, may be seen if we disregard the 10- and 12-fruit bags, inasmuch as the operation was set up for 11 fruit to make the desired weight for each 5-pound bag during the period when the samples were taken. Therefore, given a quantity of bags packed with fruit by the same method for a specified bag weight, the individual bag weights can be expected to vary above and below their average weight in a normal distribution pattern. Only 75 of the 100 bags in figure 2 contained 11 fruit. Of the others, 20 bags contained 12 fruit and 5 bags contained 10 fruit. The effect of irregularity in number of fruit per bag on variability of bag weights is indicated by the much higher standard-deviation value of 0.26 pound for all bags in the sample, compared to 0.12 pound for bags containing 11 fruit. This also shows the three-standard-deviation range, or interval, and illustrates how the standard deviation serves to measure variability in bag weights. Calculation of the standard-deviation value involves the amount by which each item deviates from the average of the measurements of the group or sample of items involved; therefore, it provides a measure of variability of the items in a sample that is then applicable to commercial operation for given operating conditions represented by the sample.

Table 2.—Normal curve areas[1]

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990

[1] This table is abridged from Table I of *Statistical Tables and Formulas*, by A. Hald (New York: John Wiley & Sons, Inc., 1952). Reproduced by permission of A. Hald and the publishers, John Wiley & Sons, Inc.

On the basis of research data, average bag weights calculated for three standard deviations above 5.25 pounds are about 0.12 pound lower for oranges in correct-count bags only than when all bags in the same sample are included. Similarly, the average bag weight for grapefruit packed in correct-count bags only is about 0.16 pound lower than when all bags are included.

In operating an automatic continuous-weighing scale, the following formula is useful for calculations involved in setting "accept" and "reject" bag weights, i.e., weight limits, either upper or lower, on what is acceptable and above or below which there will be reject action:

$$z=\frac{x-\mu}{\sigma},$$

where z=number of standard deviations,
x=selected upper or lower packed-bag weight limit (pounds),
μ=desired average bag weight (pounds),
and σ=standard deviation of bag weight (pounds).

For example, assume that the scale is set to reject overfilled bags (12 fruit) in the distribution shown in figure 2 and that x=6.10 pounds, the weight of the 12-fruit bag for the upper weight limit; μ=5.89 pounds, the average weight of the 11-fruit bags; and σ=0.12 pound, the standard deviation calculated on weights of the 11-fruit bags; then $z=(6.10-5.89)\div0.12=1.75$ standard deviations for 11-fruit bags. Referring to a table of normal curve areas (table 2) we find that a z value of 1.75 standard deviations gives a value of 45.99 percent. Relating this to a total of 50 percent (these tables give values in terms of one-half of the whole area under the normal curve), the result, which would be useful to packinghouse management, is that approximately 4 percent (50.00−45.99) of the 11-fruit bags in an output quantity represented by the sample would be rejected along with the 12-fruit bags at a scale setting of 6.10 pounds. Similarly, using the average bag weight and standard-deviation value for all bags, the resulting z value of 0.50, according to normal curve area, would mean rejection of approximately 31 percent (50.00−19.15) of an output quantity, including the 12-fruit bags, represented by the sample at the same scale setting. It should be noted, however, that this sample includes 20 percent overcount bags, whereas the average for all samples was only about 6 percent.

Two 11-fruit bags above 6.10 pounds and one 12-fruit bag below that weight (fig. 2) illustrate the impossibility of perfect separation of items according to chosen "accept" and "reject" grouping in situations of this nature. The end result in separation depends upon the reject limit chosen in conjunction with the variability and distribution characteristics of the items (bags of fruit) involved.

CONTROLLING AVERAGE BAG WEIGHT

In addition to the possible increased revenue from correcting overcount bags (table 3), the average bag weight could be reduced by means of automatic continuous-weighing scales. Average bag weights from sample lots and the three-standard-deviation range for the respective lots (fig. 1) indicate that the average bag weight must not be lower than about 5.75 pounds in order to insure that virtually none would weigh less than 5.00 pounds and only about 0.50 percent of the total output less than 5.25 pounds. However, with the scale continuously monitoring bag weights and the automatic reject mechanism rejecting bags weighing less than 5.25 pounds, management would be free to reduce average bag weight by adjusting the sizing of fruit and thus save substantially on the weight of fruit required for packing a given number of bags (table 4). In doing this, the number of rejected bags requiring rehandling would increase as the average bag weight was reduced, i.e., bringing it down closer to 5.25 pounds. Through normal distribution relationships, the number of rejected bags expected for a given average weight of bags flowing from the packing machines may the calculated. For example, for an average bag weight of 5.65 pounds and rejection of bags weighing less than 5.25 pounds,

$$z=\frac{5.25-5.65}{0.20}=\frac{-0.40}{0.20}=-2.00 \text{ standard deviations.}$$

For a z value of 2.00, the table of normal curve areas (table 2) gives 47.72 percent as the portion of the normal curve area that would be included between the given average bag weight and chosen reject weight. Interpreting this for packinghouse use, 2.28 percent (50.00−47.72) of the total bags flowing to the scale would be expected to weigh less than 5.25 pounds and thus be rejected.

For a lower average bag weight, 5.55 pounds,

Table 3.—Possible additional number and value of 5-lb polyethylene bags of fruit as result of correcting overcount bags[1]

Type of fruit and volume packed[2]	No. additional bags of fruit per each type of bag		Total No. both types of bags[4]	Value of additional packed bags[5]	
	Film[3]	Net[3]		Total, each type of fruit	Total, all fruit
ANNUAL VOLUME OF 150,000 OVERCOUNT BAGS					
Oranges—90,000 bags	3,273	4,909	8,182	$3,672	$8,838
Grapefruit—60,000 bags	6,000	4,000	10,000	5,166	
ANNUAL VOLUME OF 270,000 OVERCOUNT BAGS					
Oranges—162,000 bags	5,891	8,836	14,727	$6,609	$15,908
Grapefruit—108,000 bags	10,800	7,200	18,000	9,299	

[1] Calculated on 6 pct of annual volumes of 2,500,000 and 4,500,000 5-lb bags (table 4).

[2] Comprised of 60 pct oranges and 40 pct grapefruit, the proportions of oranges and grapefruit in total quantity shipped in 5-lb bags as shown in Fresh Citrus Container Analysis 1976–77, Statewide, Division of Fruit and Vegetable Inspection, Florida Department of Agriculture and Consumer Services.

[3] Oranges = 40 pct in film bags and 60 pct in net bags. Grapefruit = 60 pct in film bags and 40 pct in net bags. From same source given in footnote 2.

[4] Calculated on 11 oranges per bag and 6 grapefruit per bag; quantity of fruit usable for additional bags based upon 1 fruit per bag obtained in correcting the specified annual volume of overcount bags.

[5] Calculated on f.o.b. price per bag of $0.435 for oranges in film bags and $0.458 in net bags; $0.507 for grapefruit in film bags and $0.531 in net bags.

Table 4.—Weight and value of fruit that can be saved by adjusting for reduced average bag weight

Annual volume	Average bag weight (lb)	Weight of fruit saved (pounds)				Value of fruit saved[1]		
		Per bag[2]	Total, all fruit[3]	Oranges[4]	Grapefruit[4]	Oranges	Grapefruit	Total
2,500,000 bags	5.65	0.10	235,000	141,000	94,000	$8,968	$6,928	$15,896
	5.55	.20	470,000	282,000	188,000	17,935	13,856	31,791
4,500,000 bags	5.65	.10	423,000	253,800	169,200	16,142	12,470	28,612
	5.55	.20	846,000	507,600	338,400	32,283	24,940	57,223

[1] Calculated on bulk fruit f.o.b. price corresponding to $3.00 per 4/5-bu box in 1977 differential schedule by Florida Citrus Mutual ($2.80 per 44 lb for oranges; $2.80 per 38 lb for grapefruit).

[2] Relative to average bag weight of 5.75 pounds.

[3] Calculated on 94 pct of bags since correction of overcount number of fruit per bag has been shown as source of savings on 6 pct of bag output.

[4] Based upon 60 pct oranges and 40 pct grapefruit, per reference in footnote 2, table 3.

and the same rejection of bags weighing less than 5.25 pounds, 6.68 percent of the bags flowing to the scale would be expected to weigh less than 5.25 pounds and thus be rejected. Results from these two average-weight levels for 5-pound bags show the pattern of increasing numbers of rejected bags as the average bag weight is reduced. The standard deviation of bag weight used in the calculations, 0.20 pound, is a round figure slightly higher than 0.17 pound, the weighted-average standard deviation of all samples (correct-count bags) involved in the study. The effect of this is to assure conservative results, i.e., more rejected bags and additional costs dependent upon rejected bags than would be shown using 0.17 pound in calculations.

The relationship between variability in bag weights and variability in weights of individual fruit going into the bags received consideration during the study and in analyzing the data. A mathematical relationship does apply and is represented by the formula

$$\sigma_b = \sqrt{n} \times \sigma_f,$$

where σ_b=standard deviation of bag weights (pounds),
n=specified number of fruit per bag,
and σ_f=standard deviation of weights of individual fruit with which bags are filled (pounds).

In accordance with the formula, variability in bag weights (standard deviation of bag weight) will increase or decrease with the corresponding change in variability in weights of individual fruit (standard deviation of fruit weight). This formula provides a way to predict the variability in bag weights from data on individual fruit weights in a given lot where this would be helpful. Also, using the individual fruit-weight data, an average weight per fruit may be computed which, in turn, serves in calculating predicted average bag weight, the product of a specified number of fruit per bag and the average fruit weight. Thus, the resultant average bag weight is the base for addition and subtraction of standard-deviation values to obtain upper and lower limits for the weight range in which a percentage of bags would be expected to fall according to

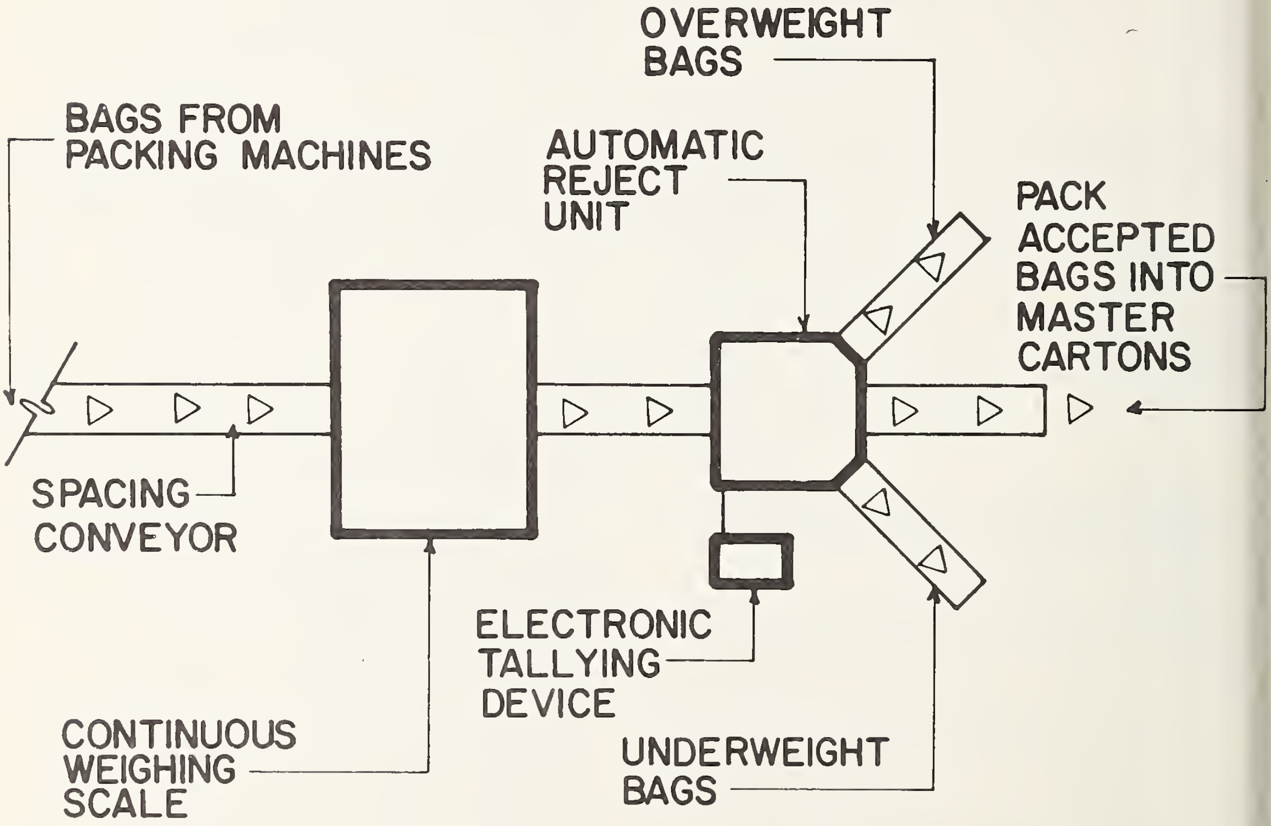
OVERWEIGHT BAGS
BAGS FROM PACKING MACHINES
AUTOMATIC REJECT UNIT
PACK ACCEPTED BAGS INTO MASTER CARTONS
SPACING CONVEYOR
ELECTRONIC TALLYING DEVICE
CONTINUOUS WEIGHING SCALE
UNDERWEIGHT BAGS

Figure 3.—Basic layout for automatic continuous-weighing scale and accessories.

normal curve-area relationship with the respective standard-deviation value.

The change required in average diameter of fruit to change average bag weight by 0.10 pound is small, probably less than would usually be realized. Starting with a given average bag weight and the number and average diameter of fruit in the pack, the calculations are easily made. A ratio of average bag weight, for example, 5.65 to 5.75 pounds, is 0.983. This ratio is applied to the volume of an individual fruit, calculated on the average diameter of fruit being packed in the 5.75-pound bags. The resultant volume figure is then used for calculation of the average fruit diameter that will make the lower average bag weight (5.65 pounds), with the pack kept the same in other respects.

Actually, with values from the study data as a basis, the calculated change in average diameter of oranges in an 11-fruit bag is from 3 to 2.98 inches to reduce average bag weight from 5.75 to 5.65 pounds. To reduce average bag weight to 5.55 pounds, for the same pack, the calculated average fruit diameter would be 2.97 inches. For grapefruit packed six per bag, the calculated

Table 5.—Initial investment and annual ownership costs for equipment

Equipment	Initial cost per unit[1]	Expected life (years)	Annual costs: Depreciation	Annual costs: Interest[2] (9 pct)	Annual costs: Insurance and taxes (4 pct)	Annual costs: Total per unit
Scale	$5,300	8	$662.50	$268.31	$212.00	$1,142.81
Spacing conveyor	2,500	8	312.50	126.56	100.00	539.06
Reject unit	500	8	62.50	25.31	20.00	107.81
Tallying unit	95	8	11.88	4.81	3.80	20.49

[1] Based on 1977 prices.

[2] Computed on average of values at beginning of first and last years of estimated life.

Table 6.—Annual ownership and operating costs for equipment

Equipment	Ownership cost	Operating costs: Power[1]	Operating costs: Maintenance[2]	Operating costs: Total	Total cost per unit	No. units	Total cost
VOLUME OF 2,500,000 5-LB BAGS							
Scale	$1,142.81	$29.00	$132.00	$161.00	$1,303.81	1	$1,304.00
Spacing conveyor	539.06	44.00	62.00	106.00	645.06	1	645.00
Reject unit	107.81	7.00	12.00	19.00	126.81	1	127.00
Tallying unit	20.49	8.00	2.50	10.50	30.99	3	93.00
Total cost, all units	...	...	...	...	...	..	2,169.00
VOLUME OF 4,500,000 5-LB BAGS							
Scale	$1,142.81	$52.00	$238.00	$290.00	$1,432.81	1	$1,433.00
Spacing conveyor	539.06	79.00	112.00	191.00	730.00	1	730.00
Reject unit	107.81	13.00	22.00	35.00	142.81	1	143.00
Tallying unit	20.49	13.00	4.00	17.00	37.49	3	112.00
Total cost, all units	...	...	...	...	...	..	2,418.00

[1] Based on $0.035 per kWh; scheduled operating hours, 833 for 2,500,000 bags and 1,500 for 4,500,000 bags.

[2] Based on 3 pct of initial cost per 1,000 h of scheduled operating time for equipment.

change in average fruit diameter is from 4.03 to 4.01 inches to reduce average bag weight from 5.75 to 5.65 pounds and to 3.98 inches to further reduce average bag weight to 5.55 pounds.

PROPOSED EQUIPMENT

The equipment consists of a spacing conveyor, continuous-weighing scale, reject mechanism, and electronic tallying device. A basic layout for such a scale installation in packinghouses is shown in figure 3. All the equipment items are well known in commercial supply channels. Firms having the capability to construct belt conveyors might, under some conditions, find it advantageous to do so for some conveyor sections involved in their particular installation. Electronic tallying devices, though not essential, could help significantly in effective supervision of operations as well as saving labor that might otherwise be engaged in manually counting bags and recording information. The initial cost is about $95 (table 5) for each item of information, i.e., overweight bags, underweight bags, and accepted bags.

REVENUE AND COST FACTORS

Partially offsetting the savings shown in preceding sections are significant additional costs for the continuous-weighing method, as follows: (1) ownership and maintenance costs for the scale and accessories, (2) labor costs for handling and emptying the rejected bags of fruit, and (3) cost of rejected bags.

Table 7.—Estimated labor costs for handling 5-lb bags rejected for specific conditions when using automatic continuous-weighing equipment

Reject condition	Reduction in average bag weight (lb)	Annual volume					
		2,500,000 bags			4,500,000 bags		
		Scheduled operating time (h)	No. workers[1]	Labor cost[2]	Scheduled operating time (h)	No. workers[1]	Labor cost[2]
Overcount	...	833	1	$2,291	1,500	1	$4,125
Underweight	0.10	833	1	2,291	1,500	1	4,125
Do	.20	833	1	2,291	1,500	2	8,250

[1] Determined with reference to an estimated maximum rate of 185 bags per man hour for manually handling and emptying bags rejected by scale. Mostly, for whole numbers of workers allowed, the result is a lower rate of expected output per man hour.

[2] Calculated on hourly wage of $2.75.

Table 8.—Numbers and costs of 5-lb polyethylene bags involved in correcting for overcount filling[1]

Annual volumes[2]	Type of fruit packed	No. each type of bag[3]		Cost of bags					
				Per 1,000, each type of bag[4]		Total, each type of bag		Total, both types of bags	Total, all bags
		Film	Net	Film	Net	Film	Net		
150,000 bags	Oranges	36,000	54,000	$19.35	$40.10	$ 697	$2,165	$2,862	$4,786
	Grapefruit	36,000	24,000	22.30	46.70	803	1,121	1,924	
270,000 bags	Oranges	64,800	97,200	19.35	40.10	1,254	3,898	5,152	8,614
	Grapefruit	64,800	43,200	22.30	46.70	1,445	2,017	3,462	

[1] Assumed that discarded bags would not be put to any use. 6 pct of bags contained 1 extra fruit.

[2] See footnote 1, table 3. Comprised of 60 pct oranges and 40 pct grapefruit, the proportions in total quantity of oranges and grapefruit shipped in 5-lb bags; from same source given in footnote 2, table 3.

[3] See footnote 3, table 3.

[4] From Florida Citrus Mutual data.

Tables 5 and 6 show the initial investment and ownership and operating costs for the scale, reject unit, and other accessories. The initial costs given are for equipment designated by the supplier to have capability for speeds up to 120 packages per minute and package weights up to 10 pounds.

Labor costs estimated for the handling involved in emptying fruit from the bags rejected by the scale for the designated conditions are given in table 7. Packinghouses have not had an established activity of this kind and, therefore, a time-study basis of development was not possible.

The costs of bags involved in correcting for overcount filling are shown in table 8. The costs of bags involved as underweight in adjusting for reduced average bag weight are shown in table 9.

The combined values of additional packed bags from correcting of overcount bags and fruit saved by adjusting for reduced average bag weight are given in table 10. The combined effect of possible increased returns and additional costs (table 10) is a net increase in annual revenue ranging from $11,488 for the lowest annual volume of bags and least degree of control of average bag weight to $40,710 at the opposite end of the scale of comparative conditions. Even with the projected additional costs for bags to take the place of those rejected and for labor incident to handling the rejected bags, the smallest projected net increase in revenue is sufficient to more than pay the initial cost of equipment in 1 year.

CONCLUSIONS

Automatic continuous-weighing equipment, used for maintaining specified weight on bags packed by means of count-action machines, offers the following principal potential benefits:

1. Rejecting overcount bags for correction to save fruit.
2. Reducing average bag weight to save fruit, through sizer adjustment, with assurance against shipping underweight bags by virtue of the automatic reject function of the scale equipment.
3. Eliminating unnecessary discarding of undercount bags that meet minimum weight requirement.

The amount of net savings projected for the foregoing potential benefits is substantial (table 10).

Table 9.—Costs of 5-lb polyethylene bags involved as underweight in adjusting for reduced average bag weight[1]

Adjusted annual volumes[2]	Type of fruit packed	Percentage of bags rejected	Underweight (rejected) bags: Total, all bags	Underweight (rejected) bags: No. each type of bag[3]: Film	Net	Cost of bags: Per 1,000 for each type of bag[4]: Film	Net	Cost of bags: Total, each type of bag: Film	Net	Cost of bags: Total, both types of bags	Cost of bags: Total, all bags
			ANNUAL VOLUME OF 2,500,000 BAGS								
2,350,000 bags ...	Oranges	2.28	53,580	12,859	19,289	$19.35	$40.10	$249	$773	$1,022	$1,709
	Grapefruit ..			12,859	8,573	22.30	46.70	287	400	687	
2,350,000 bags ...	Oranges	6.68	156,980	37,675	56,513	19.35	40.10	729	2,266	2,995	5,008
	Grapefruit ..			37,675	25,117	22.30	46.70	840	1,173	2,013	
			ANNUAL VOLUME OF 4,500,000 BAGS								
4,230,000 bags ...	Oranges	2.28	96,444	23,146	34,720	$19.35	$40.10	$448	$1,392	$1,840	$3,077
	Grapefruit ..			23,147	15,431	22.30	46.70	516	721	1,237	
4,230,000 bags ...	Oranges	6.68	282,564	67,815	101,723	19.35	40.10	1,312	4,079	5,391	9,014
	Grapefruit ..			67,816	45,210	22.30	46.70	1,512	2,111	3,623	

[1] Assumed that discarded bags would not be put to any use.

[2] Excludes 6 pct of annual volume for overcount bags. Comprised of 60 pct oranges and 40 pct grapefruit, the proportions of oranges and grapefruit in total quantity shipped in 5-lb bags; from same source given in footnote 2, table 3.

[3] See footnote 3, table 3.

[4] From Florida Citrus Mutual Data.

Table 10.—Combined revenue and cost effects as result of using automatic continuous-weighing equipment

Annual volumes	Reduction in average bag weight (lb)	Increase in revenue from—			Individual costs						
		Additional packed bags[1]	Fruit saved[2]	Total, both revenue sources	Labor, reduced average weight[3]	Bags, reduced average weight[4]	Equipment[5]	Labor, overcount bags[6]	Bags, overcount filling[7]	Total, all costs	Total net increase in revenue[8]
2,500,000 bags	0.10	$8,838	$15,896	$24,734	$2,291	$1,709	$2,169	$2,291	$4,786	$13,246	$11,488
	.20		31,791	40,629	2,291	5,008				16,545	24,084
4,500,000 bags	.10	15,908	28,612	44,520	4,125	3,077	2,418	4,125	8,614	22,359	22,161
	.20		57,223	73,131	8,250	9,014				32,421	40,710

[1] From table 3. Result of correcting overcount bags.

[2] From table 4. Result of adjusting for reduced average bag weight.

[3] From table 7.

[4] From table 9.

[5] From table 6.

[6] From table 7.

[7] From table 8.

[8] Net increase obtained by subtracting total costs from totals of both revenue sources.

Existing equipment layouts may involve difficulties in conveying bags to one scale unit from as many packing machines as are necessary to properly utilize its capacity. In these circumstances, decision on a course of action would be governed by comparative costs of alternatives such as additional scale units and changes in layout of other equipment.

Where the current method of machine-packing bags includes operator placement of packed bags into master cartons at each machine, changes would be necessary to permit centralizing the master cartoning activities at a location following the scale unit.

The formulas and calculations shown in this report are not difficult to follow. However, no large amount of calculations would be required of managerial or other packinghouse personnel. For general use, when dealing with 5-pound bags, a standard deviation of 0.20 pound may be used for σ (standard deviation) in the z formula. This value is based upon study data and is an approximate average for all samples involved. Its use is suggested on the premise that the effect in possible lack of maximum accuracy in a given situation would be more desirable than the time and interruption involved for personnel to make computations of standard-deviation values for every desired situation. Hand-held calculators, preprogramed for standard deviation, are widely available at prices (in 1977) well below $100 should management wish to make more calculations for different conditions.

Weight limits and average weight for bags are generally chosen in the light of relevant operating conditions and the practice that management wishes to follow, without need to calculate the values. Normally, a very small change in sizer setting would control average bag weight to save on the amount of fruit in packing a given quantity of bags. The proper setting could be reached by making use of bag-weight readout provided by the electronic tallying device connected to the scale, i.e., adjusting the sizer until the averages of the weight readings for several groups of bags (possibly 10) indicate satisfactory agreement with the average weight desired. In using the scale equipment without tallying accessories, personnel would weigh randomly chosen packed bags, possibly in groups of 10, and adjust the sizer until the average bag weight obtained from the samples agreed with the desired average bag weight.

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